ARCHES NATIONAL PARK
RESEARCH SUMMARY 2012

1) Study Title: The Moab Project Site Environmental Air Monitoring Program Conducted by the U.S. Department of Energy's Grand Junction Office
Permit No.: ARCH-2010-SCI-0001
Principle Investigator: Ed Baker
Purpose of Scientific Study: DOE's environmental air monitoring program will monitor local and background air quality for various radioparticulates (Uranium, Th-230, Ra-226 and radon-222) and radon gas and direct gamma.
Findings/Accomplishments for 2012: The air monitoring station at Arches (east side of visitor's center) is one of 14 stations operated by the US Department of Energy to detect levels of radiation on the DOE mill tailings site and surrounding locations. The Arches station is ~1/4 mile down wind of the project activities. No elevated levels of radiation have been detected at Arches. As tailings is excavated and transported to Crescent Junction the Arches station will continue to record data. See DOE "Environmental Air Monitoring Data Report" on the Moab UMTRA Project web site: http://www.gjem.energy.gov/moab for more information.

2) Study Title: NCPN Integrated Riparian Monitoring in Arches National Park
Permit No.: ARCH-2012-SCI-0001
Principle Investigator: I&M NCPN
Purpose of Scientific Study: The National Park Service's Inventory and Monitoring Program (NPS I&M), in collaboration with 32 monitoring networks, are charged with monitoring natural resources. Vital signs represent a select set of physical, chemical and biological elements and processed of park ecosystems that are chosen to represent the overall health and condition of a park's resources. Together, the Northern and Southern Colorado plateau Networks (NCPN and SCPN) have developed conceptual models of key ecosystems and identified an integrated set of vital signs for tracking resource conditions at 35 NPS units within or near the Colorado Plateau (Thomas et al. 2004, OâDell et al. 2005). Riparian systems are a high priority vital sign for the NCPN (OâDell et al. 2005).

Riparian systems are disproportionately high inbiodiversity relative to their spatial extent due to the year-round or at least frequent availability of water. In turn, healthy and natural riparian systems serve as a predictable source of water, and function to maintain the natural diversity of riparian-adapted plants and animals across the Colorado Plateau region. Various dynamics interact to influence riparian systems. Ground-water levels, flood

disturbance intensity and frequency, plant population, dynamics, and even upland conditions and dynamics collectively interact to shape the in-stream conditions and vegetative features of a riparian zone. Monitoring the status and trends in representative attributes and effects of an array of patterns and processes is an overarching goal of the NCPN Integrated Riparian Monitoring effort. This effort is intended to provide park managers with information on the variability of riparian systems, and to provide early warning of system degradation. In the latter case, monitoring information can be used to determine the potential for mitigating actions, and where such actions are implemented, monitoring efforts can contribute to understanding the effects of these actions.

Riparian monitoring occurs in Courthouse Wash in ARCH. Specific objectives of the overall riparian monitoring effort are to determine the status and trends in:

1) the areal extent, cover, species composition and structure of riparian vegetation
2) exotic plant species
3) channel morphology of surveyed cross sections and the channel thalweg
4) floodplain ground-water levels and stream flow/discharge

Procedures for riparian monitoring incorporated pieces of the USGS Water Quality Assessment Program (Moulton et al. 2002) and EMAP procedures (Kaufmann et al. 1999) and were initially developed by Scott and Reynolds (draft). Further refinement has been completed by NCPN staff and by Steve Monroe and Ellen Soles of the SCPN. NCPN riparian protocols have been submitted for peer review.

Findings/Accomplishments for 2012: NCPN field crews monitored riparian vegetation in two reaches in 2012 in Courthouse Wash: Reach 7 was revisited and Reach 5 was established . A geomorphic survey using a total station was established in Reach 7. Hydrologic data from two wells in Reach 1 were collected continuously and downloaded. Monitoring crews will return in 2013.

3) Study Title: DUST DEPOSITION AND WIND EROSION MEASUREMENTS, ARCHES NATIONAL PARK

Permit No.: ARCH-2012-SCI-0002

Principle Investigator: Marith Reheis

Purpose of Scientific Study: The eastern Colorado Plateau is an area that is vulnerable to wind erosion due to its semiarid climate and sandy soils. Much of the nutrients in these soils have been contributed over thousands of years by additions of aeolian dust from both local and distant sources. Loss of these nutrients by wind erosion depletes the soils and potentially stresses native vegetation. This proposal is to maintain, and monitor for many years, an existing site near Devils Garden with instruments that measure horizontal aeolian sediment transport

(using a BSNE) and vertical dust deposition (marble dust traps), as part of a regional study with several other monitoring sites in Canyonlands National Park and surrounding BLM lands.
Findings/Accomplishments for 2012: Samples were collected from the Devils Garden (CP-3) site three times during 2012: early March, early June, and early November. BSNE samples were weighed and discarded. Dust trap samples were analyzed by USGS for weight, soluble salt content, particle size, and total carbon and inorganic carbon contents.

4) Study Title: U.S. Geological Research in Arches NP (NOTE: this is a continuation of previous studies ARCH-0008 and ARCH-00046.)
Permit No.: ARCH-2012-SCI-0003
Principle Investigator: Jayne Belnap
Purpose of Scientific Study: Future changes are expected to affect native plant communities, biocrusts (composed of cyanobacteria, lichens, and mosses), and normal water and nutrient cycles in desert systems. These particular ecosystem processes are threatened by climate change (both altered temperature and precipitation), the compressional forces generated by the trampling of people and off-road driving, and invasive plants (especially annual weeds).

Climate change:
Temperatures are expected to rise by up to 6 Â°C by the year 2100 in this region. Models predict precipitation to show up to a 20% decline. Even with no change in precipitation, higher temperatures will decrease soil moisture by around 30%, stressing plants and biocrusts.
Compressional forces:
Soil compaction and disruption of biocrusts via trampling can result in decreased water availability to vascular plants through decreased water infiltration and increased albedo with possible decreased precipitation. Surface disturbance also generally causes accelerated soil loss through wind erosion, with a concomitant decline in soil fertility, and decreased diversity and abundance of soil biota.
Invasive annual plants:
Many sites on the Colorado Plateau have been, or are being, invaded by annual weeds. Most of these sites have deep soils and were dominated by perennial grasslands before this invasion. During drought times, these plants do not germinate, leaving soils exposed to wind erosion.

This project addresses how climate change, land use, invasive of annual grasses and the interaction among these components will affect native plants and biocrusts and as a consequence, soil stability. We will collect dust produced from sites using BSNEs, a standary dust collection trap.
Findings/Accomplishments for 2012: Dust network (BSNE)

We collected dust from BSNEs at three sites in Arches in spring (March), summer (late June), and Fall (late Oct). Dust amounts ranged from 1.1 to 7.9 grams over the year with amounts highest in summer in contrast to the trend in 2011 of steadily increasing from spring through fall. Dust levels were 2-3 times greater at 15 cm than at heights of 50 and 100 cm.

5) Study Title: Nitrogen deposition in the National Parks of the Four Corners region
Permit No.: ARCH-2012-SCI-0004
Principle Investigator: Sasha Reed
Purpose of Scientific Study: Nitrogen (N) deposition in the western U.S. is on the rise and is significantly affecting terrestrial ecosystems. For example, N deposition has repeatedly been shown to lower air quality, increase greenhouse gas emissions, alter plant community composition, reduce water quality, and significantly modify fire regimes. Accordingly, the effects of N deposition represent one of our largest environmental challenges and make difficult NPS's mission to "preserve the scenery and the natural and historic objects and the Wildlife unimpaired for the enjoyment of future generations". Due to increased population growth and energy development, the Four Corners region has become a notable "hotspot" for N deposition, however, our understanding of how increased N deposition will affect these unique ecosystems remains notably poor. This project represents multi-disciplinary approach to gathering information that will help NPS safeguard the Four Cornerâs national parks, both now and into the future. We will use modeling, field, and laboratory techniques to clarify current N deposition gradients and to elucidate the ecosystem consequences of N deposition to the national parks of the Four Corners. This NPS-funded research will ultimately lay the foundation to elucidate thresholds and deposition effects on soil and plant communities and will provide the basis for upcoming field fertilization experiments to link N deposition, exotic plant invasion, fire regimes, and ecosystem function in the national parks of the Four Corners region.
Findings/Accomplishments for 2012: We have been actively fertilizing and monitoring the 60 plots present within Arches National Park. Interestingly, this spring was notably dry (as part of a drought that occurred throughout the Southwest) and we observed zero cheatgrass germination in all of the fertilization plots. We collected soil and foliar (from Achnatherum hymenoides plants that are centered within each plot) data that show that the added N is having subtle effects on soil and plant N concentrations, but perhaps due to the overriding effect of climate (i.e., the drought), we observed no effects of fertilization on cheatgrass abundance. We are excited to see what happens this year (as the winter has provided a lot of long-standing snow to date) and to observe, if this is indeed a wetter spring, how nitrogen deposition not only continues to affect soil and native plant biogeochemistry, but the germination of cheatgrass as well.

6) Study Title: NCPN Integrated Upland Monitoring in Arches National Park
Permit No.: ARCH-2012-SCI-0005
Principle Investigator: I&M NCPN
Purpose of Scientific Study: The Northern Colorado Plateau Inventory and Monitoring Network (NCPN) of the National Park Service has identified upland ecosystem characteristics, processes, vegetation, and other biota as vital signs to be monitored. Upland monitoring is intended to strike a balance between increasing fundamental understanding of dryland systems and providing managers early warning of undesirable change. It will document the variability in these systems while providing information needed for resource management decisions. Addressing these two goals will be accomplished partly through sampling design and data analysis. Some sites may be selected as representative of large portions of the landscape, others because of their management history. Evaluation of upland monitoring data in relation to other vital signs will facilitate identification of drivers and distinguishing natural from anthropogenic change. Additionally, plot data from this effort will be used in the classification and interpretation of remotely sensed data.

NCPN upland monitoring objectives for selected vegetation types/ecological sites:

1) Determine status and trends in plant communities including:
-overall species richness (all vegetation types)
-cover of vegetation by dominant species and life form (all vegetation types)
-density of shrubs by size class (all vegetation types)
-basal area and density of tree species (in forests, woodlands, and Gambel oak)
-canopy closure (in forests)
-fuel loading (in forests and woodlands)
-frequency of exotic invasive species (all vegetation types)
2) Determine status and trends in soil stability including:
-cover of biological soil crusts by morphological group (cyanobacteria, lichen, moss, and undifferentiated crust; all vegetation types)
-cover of other surface features (litter, rock, bare ground, etc.; all vegetation types)
-soil aggregate stability (in grasslands, shrublands, and woodlands)
-canopy-gap size (as an indicator of wind erosion potential; in grasslands and shrublands)
3) Determine status and trends in hydrologic function including:
-basal-gap size (in grasslands and shrublands)

Findings/Accomplishments for 2012: The NCPN field crew monitored 24 plots in 2012, including 8 deep blackbrush, 8 grassland, and 8 pinyon-juniper/blackbrush plots. 12 plots were newly established. All plots were checked for cultural resources during reconnaissance and again during establishment. A draft summary report of 2011 data was completed and sent to resource management staff.

7) Study Title: Structural development of accommodation zones in host and suprajacent sediments associated with the development of salt walls: implications for sub-surface hydrocarbon flow
Permit No.: ARCH-2012-SCI-0006
Principle Investigator: Stuart Clarke
Purpose of Scientific Study: Salt walls and related structures provide ideal geometries for the accumulation of hydrocarbons. However, these structures are poorly understood in terms of their three-dimensional geometry and dynamics, and are difficult to interpret using seismic reflection data alone. This study aims to characterise the geometry and development of fault systems related to the dissolution of salt walls and the subsequent collapse of the overlying sediments. Detailed field mapping and collection of geometrical measurements from Arches NP and surrounding areas will be used to construct three-dimensional computer models, which can be used to evaluate the development of some of these key structures, and to assess the impact that their geometry might have on the flow of hydrocarbons. The models will later be used to develop a structural framework with which to guide seismic interpretation across salt structures in active hydrocarbon provinces, such as the Gulf of Mexico and the U.K. Central North Sea.
Findings/Accomplishments for 2012: Field mapping and data collection have been carried out for key areas including the Moab Anticline (nr entrance to Arches NP), and Salt and Cache Valleys. Data are used to develop three-dimensional fault models. Models are in the process of being validated via two- and three-dimensional numerical balancing techniques. Results will be used to draw comparisons with equivalent structures from the UK Central North Sea during 2013. Fracture population data are being processed to provide new insights into salt anticline collapse mechanisms. Further fracture data collection is scheduled for May 2013.

8) Study Title: Plant Communities (Vegetation)
Permit No.: ARCH-2012-SCI-0007
Principle Investigator: Robert Webb
Purpose of Scientific Study: Repeat photography is a long-established technique for documenting landscape change and estimating plant demographics, particularly in arid environments. Although remotely sensed imagery, such as Landsat or MODIS data, provides spatially rectified information, repeat photography can provide long-term, species-specific information that is extremely important for documenting the effects of land-use practices and climatic change. On the Colorado Plateau, where long-term ecological data from permanent plots is sparse, repeat photography is the best technique for documenting changes in shrublands and grasslands over the last century of climate variability. Approximately 475 historical images of Canyonlands and Arches National Parks and Hovenweap and Natural

Bridges National Monuments were collected in the early 2000s, and approximately 138 were matched between 2000 and 2006. The original photographs were taken as early as 1871 (Powell expedition) and 1874 (William Henry Jackson), and many originals were taken between 1905 and 1925 by U.S. Geological Survey geologists. We request funding to interpret landscape change and plant demographics for the already replicated photographs and to replicate selected additional imagery to provide data on specific types of ecosystems that are expected to be impacted by future climate changes.
Findings/Accomplishments for 2012: We conducted field work in Canyonlands National Park (Maze District, Island in the Sky District), at Natural Bridges NM, and Hovenweap NM, matching approximately 200 historical photographs. More importantly, we have converted an old database into a more usable system for future work.

9) Study Title: Assessing Climate Refugia and Connectivity for Desert Bighorn Sheep
Permit No.: ARCH-2012-SCI-0009
Principle Investigator: Clinton Epps
Purpose of Scientific Study: (Note: the Detailed Implementation Plan for this study has been signed by Kate Cannon, the Superintendent of the Southeast Utah group, and Jeff Troutman, formerly the Resource Management Division Chief for the Southeast Utah group.)

Management of wide-ranging species with fragmented distributions offers a difficult challenge on NPS lands, particularly in the face of regional or global shifts in climate. Desert bighorn sheep (Ovis canadensis nelsoni) exemplify that challenge. This charismatic, desert-adapted animal exists in relatively small, sometimes isolated populations scattered across the arid southwestern United States. Recent research has firmly linked desert bighorn sheep persistence and genetic diversity with climate variation (Epps 2004; Epps et al. 2004, 2006), and reproduction and survival for this species are predicted in large part by precipitation and temperature (Wehausen 2005). However, high rates of population extinction (e.g., Wehausen 1999) may be mitigated by recolonization from other nearby herds (e.g., Epps et al. 2010). While climate is intractable to management at the regional level, maintaining connectivity among existing populations of bighorn sheep will provide the best means for offsetting the unpredictable but potentially devastating changes in precipitation and temperature predicted for the American southwest.

Historically, management of desert bighorn sheep was approached on a population by population basis. Growing recognition that desert bighorn sheep are subject to metapopulation dynamics (frequent extinction and recolonization of small populations in discrete habitat patches) has made it clear that desert bighorn sheep must be managed at a regional level. This is particularly true given that many processes that affect bighorn sheep, such as climate

variation or climate change, are correlated at regional scales. Human-driven landscape change is also happening at an unprecedented scale, as demonstrated by proposed massive solar developments in the Mojave Desert and the US-Mexico border fence (Flesch et al. 2010). National Park Service lands support significant populations of desert bighorn sheep in at least nine parks in four states. However, in many cases the connectivity of those populations and with other populations in each region is unclear. Also unclear are the roles of those herds in regional context: are they core populations, peripheral populations, or do they serve as a critical link for gene flow and dispersal between other populations in the region? Lastly, although region-level predictions from global climate change models are often highly variable, how will anticipated changes in temperature and precipitation affect desert bighorn metapopulation structure and habitat?

Despite these uncertainties, ongoing research on desert bighorn sheep has created unprecedented opportunities to evaluate the role of bighorn sheep populations on NPS lands in the context of metapopulation persistence and climate change. We propose to use a combination of new and existing datasets to 1) analyze genetic diversity and metapopulation structure of desert bighorn on NPS and pertinent surrounding lands; 2) optimize connectivity models by augmenting existing genetic datasets; 3) explore metapopulation persistence under different climate change scenarios; and 4) identify regional refugia for desert bighorn sheep in the context of NPS lands and climate change.

Findings/Accomplishments for 2012: We collected over 900 bighorn sheep fecal samples from NPS lands and adjacent public lands in 2012 for genetic analysis. We genotyped 666 samples (collected in 2012 and previous years) and from these identified 404 unique genotypes (i.e., individuals).

Efforts specific to ARCH are as follows:

We collected 17 fecal samples from populations adjacent to ARCH on the southwest side of Highway 191. We genotyped 14 of these samples and identified 10 unique genotypes. We surveyed areas previously used by bighorn within ARCH, but did not find any recent evidence of use. An additional 48 samples were collected from BLM lands supporting bighorn populations that likely interact with those in/near the park.

Remaining fecal samples will be genotyped and genetic data will be analyzed, in combination with previously collected/genotyped samples, to reveal genetic structure of desert bighorn sheep populations on and near NPS lands. A spatial database and full report including locations of fecal samples, group sizes and locations of bighorn sheep observations, genetic data, and important waterholes will be provided to NPS at the completion of the study.

10) Study Title: Invertebrates (Insects, Other)
Permit No.: ARCH-2012-SCI-0010
Principle Investigator: Tim Graham
Purpose of Scientific Study: The tamarisk-Diorhabda elongata interaction has been studied in labs and field cages, but these studies do not provide data on the dynamics of beetle-tamarisk interactions at the landscape level. Beetle populations slosh back and forth along riparian corridors defoliating tamarisk, disperse to new territories, then subsequent generations re-colonize stands previously defoliated. Timing of defoliation, re-foliation, and re-colonization over a season or over years determine how quickly D. elongata kill tamarisks. Understanding this dynamic process is essential for managers trying to balance tamarisk control with other resources as the beetle tamarisk interactions play out across the Southwest.
Findings/Accomplishments for 2012: Tamarisk beetle adults emerged in numbers much earlier than previous years, probably driven by the warm winter and early spring weather. Total numbers of adults counted at all sites peaked about 20 days earlier in 2012 than the average for the previous 3 years; larval numbers peaked 15 days earlier that the previous 3 year average. Adults probably entered diapause in fall 2011 in very good condition because there was more tamarisk foliage re-growth in late summer 2011 than in the previous 2-3 years. The relatively short, warm winter may have stressed over-wintering beetles, but they were also able to emerge to feed earlier, and did so as evidenced by much higher numbers on the first surveys of 2012 than in the previous 3 years. There was a larger 2nd generation of larvae in 2012 than observed before, and adults actually experienced a relatively large 3rd peak in numbers than in other years.

11) Study Title: Ecological effects of stream drying under climate change in the Upper Colorado River Basin
Permit No.: ARCH-2012-SCI-0011
Principle Investigator: Lindsay Reynolds
Purpose of Scientific Study: Streamflows in late spring and summer have declined over the last century in the western US and mean annual streamflow is projected to decrease by six to 25% over the next 100 years. In arid and semi-arid regions of the western US, it is likely that some perennial streams will shift to intermittent flow regimes in response to climate-driven changes in timing and magnitude of precipitation, runoff, and evapotranspiration. We propose to address the following research question: what will be the effects of reduced low flow stream hydrology on riparian plant communities? To address this question we will sample riparian plant communities along a hydrologic gradient (perennial to intermittent) to develop statistical relationships between flow parameters and biotic responses. These statistical relationships can eventually be used to help predict biotic changes under climate change-driven stream drying.

Final products will include annual progress reports, a final report, a peer-reviewed manuscript, a final presentation, and an informational, interactive website accessible to land and water managers. The tasks included in this research will be carried out over 2 years, completed by September 2013.

Findings/Accomplishments for 2012: During 2012, we established two study sites in Arches National Park: one on Courthouse Wash and One on Salt Wash. At both sites we did a topographic survey cross section of the wash and surveyed vegetation adjacent to and associated with the wash. We obtained topographic and plant community data, as well as observational hydrologic data. We plan to analyze and write a report including these data during 2013. This final report and associated manuscripts will be completed in late 2013 and early 2014.

12) Study Title: NCPN Springs Monitoring in Arches National Park
Permit No.: ARCH-2012-SCI-0012
Principle Investigator: I&M NCPN
Purpose of Scientific Study: The National Park Service's Inventory and Monitoring Program (NPS I&M), in collaboration with 32 monitoring networks, are charged with monitoring natural resources. Vital signs represent a select set of physical, chemical and biological elements and processed of park ecosystems that are chosen to represent the overall health and condition of a park's resources. Together, the Northern and Southern Colorado plateau Networks (NCPN and SCPN) have developed conceptual models of key ecosystems and identified an integrated set of vital signs for tracking resource conditions at 35 NPS units within or near the Colorado Plateau (Thomas et al. 2004, OâDell et al. 2005).

Spring and seep systems are a high priority vital sign for the NCPN (OâDell et al. 2005). Spring and seep systems are disproportionately high in biodiversity relative to their spatial extent due to the year-round or at least frequent availability of water. Many springs are closely tied to regional climate and local weather patterns. Monitoring the status and trends of spring and seep ecosystems can provide park managers with information on the variability of spring and seep systems, early warnings of system degradation, and the impacts of climate change.

Specific objectives of the springs and seeps monitoring effort are to determine the status and trends in:

1) water quantity
2) water pH and specific conductance
2) endemic plant counts
3) vegetation species composition and cover

Monitoring will also produce status information on water quality, exotic plant and animal species presence, and anthropogenic disturbance.

Findings/Accomplishments for 2012: Monthly water quantity and quality samples were taken at Poison Ivy, Sleepy Hollow, and Seven Mile Boundary springs. A double observer pilot study of potential vegetation monitoring methods was completed at eight randomly selected hanging gardens.